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Biodiversity, species range and gene flow in the abyssal Pacific nodule province: predicting and managing the impacts of deep seabed mining

Report of the Secretary-General of the International Seabed Authority*

1. The present report summarizes the results of a joint project of the International Seabed Authority with the J. M. Kaplan Fund to study biodiversity, species range and gene flow in the abyssal Pacific nodule province. The project was carried out from 2002 to 2007. The complete final report of the project has been published by the Authority as *ISA Technical Study, No. 3* (2008). The present summary has been prepared for information purposes and for the benefit of members of the Authority during the fourteenth session.

I. Background

2. The scientific workshop held by the International Seabed Authority in Sanya in 1998 recommended that the Authority prepare an environmental studies model that would encourage cooperation among States, national scientific institutions and the former registered pioneer investors (contractors) in areas of environmental study and research. In the light of that recommendation, in March 1999 the Authority convened a small group of internationally recognized scientific experts to identify critical issues suitable for international collaboration. The experts noted that, while the general quality of the nodule ecosystems in the Clarion-Clipperton Zone is known, the actual community resistance, resilience and pattern of biodiversity are very poorly understood. This lack of knowledge makes the prediction and sound management of mining impacts difficult.

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3. These discussions led to the decision to convene a workshop in 2002 on the prospects for international collaboration in marine scientific research. The workshop focused on four key scientific issues considered appropriate for international collaboration:

(a) Levels of biodiversity, species range and gene flow in abyssal nodule provinces;

(b) Disturbance and recolonization processes at the seafloor following mining track creation and plume resedimentation;

(c) Mining plume impacts on the water column ecosystems (nutrient enrichment, enhanced turbidity, heavy-metal toxicity, enhanced oxygen demand);

(d) Natural variability in nodule province ecosystems.

4. As a result, the Kaplan project was initiated at the workshop in 2002. The aim of the project was to assess levels of biodiversity, species range and gene flow in abyssal nodule provinces. The project was funded mainly by the J. M. Kaplan Fund with additional contributions from the Authority.

II. Scope and objectives of the project

5. Abyssal Pacific sediments in the Clarion-Clipperton Zone harbour abundant mineral resources, in the form of polymetallic nodules, which are of increasing commercial and strategic interest, and may also be major reservoirs of biodiversity. However, it has so far proved difficult to quantify the threat of nodule mining to biodiversity (in particular, the likelihood of species extinctions) without better knowledge of the following:

(a) The number of species residing within areas potentially perturbed by single mining operations;

(b) The typical geographic ranges of species (and rates of gene flow) within the general nodule province.

6. Both biodiversity and species ranges remain poorly understood within the nodule province for three main reasons. First, many areas of the nodule province and dominant groups of seafloor animals (especially nematode worms and foraminifera) remain grossly undersampled. Second, while various expeditions have sampled the seafloor biota of the nodule province, each sampling programme has generally used different specialists to identify the animals from their collections. Because most species collected were new to science and have not been formally described in the scientific literature, there is no way to relate the species list of one study to that of another. Therefore, it is very difficult to compare species lists across the entire nodule province. Third, all biodiversity studies in the nodule province have used traditional morphological methods for identifying species. However, recently developed molecular methods (e.g., using the genetic information in DNA sequences) suggest that morphological techniques typically underestimate the number of species and overestimate species ranges in marine habitats.

7. Until biodiversity levels and species ranges in the Pacific nodule province are much better understood, the impacts of nodule mining (or other large-scale anthropogenic disturbances) on deep-sea biodiversity cannot be predicted. For

example, if biodiversity levels were very low within mining claims, or if most species ranges were very large compared to the scales of claim areas and potential mining disturbance, then rates of species extinctions caused by nodule mining could be low.

8. In the Kaplan project, scientists[1] used state-of-the-art molecular and morphological methods to evaluate biodiversity and geographic ranges of three key faunal groups in the abyssal Pacific nodule province: polychaete worms, nematode worms, and protozoan foraminifera. Together, these groups constitute more than 50 per cent of faunal abundance and species richness in abyssal sediments, and represent a broad range of ecological and life-history types. The primary goals of the project were as follows:

(a) To estimate, using modern molecular and morphological methods, the number of polychaete, nematode and foraminiferal species at two to three stations spaced at approximately 1,500 kilometre (km) intervals across the Pacific nodule province;

(b) To evaluate, using state-of-the-art molecular and morphological techniques, levels of species overlap and, if possible, rates of gene flow, over scales of 1,000 to 3,000 km for key components of the polychaete, nematode and foraminiferan fauna;

(c) To broadly communicate the findings to the scientific and mining-management communities, and make specific recommendations to the International Seabed Authority on minimizing the risks to biodiversity resulting from mining.

9. To address those project goals, the scientists involved in the project collected macrofaunal and meiofaunal samples, using special "DNA-friendly" techniques, at three sites spaced at intervals of approximately 1,000 to 2,000 km across the Pacific region targeted for nodule mining. The sampling programme involved three research cruises in which project personnel (8 to 20 people per cruise) spent 83 days at sea and collected a total of 40 box-core and 32 multiple-core samples. Collected samples of foraminifera, nematodes and polychaetes were then transported to laboratories in the United States, the United Kingdom, Japan and France for sorting and detailed morphological and molecular analyses. The analyses, results and syntheses have been reported as 16 presentations at international scientific meetings and workshops, and as 20 publications in the peer-reviewed scientific literature. Many more presentations and publications are planned for the future.

III. Results

10. The results from the study indicated high, unanticipated and still poorly sampled levels of species diversity for all three sediment-dwelling faunal components (foraminifera, nematodes and polychaetes) at the individual study sites. Cryptic speciation (i.e., the presence of multiple species previously identified as

[1] The principal investigators were Dr. Craig R. Smith (University of Hawaii at Manoa, United States of America); Drs. Gordon Paterson, John Lambshead and Adrian Glover (Natural History Museum of London, United Kingdom); Dr. Alex Rogers (Zoological Society of London, United Kingdom); Dr. Andrew Gooday (National Oceanography Center, Southampton, United Kingdom); Dr. Hiroshi Kitazato (JAMSTEC, Japan); Drs. Myriam Sibuet, Joelle Galeron and Lennick Menot (IFREMER, France).

single species) appeared to be very common in the polychaetes and nematodes. Habitat heterogeneity also appeared to be higher than previously appreciated. The researchers speculated that the total species richness of sediment-dwelling foraminifera, nematodes and polychaetes (a subset of the total fauna) at a single site in the Clarion-Clipperton Zone could easily exceed 1,000 species. Results from all faunal components suggested that there is a characteristic fauna of the abyss, i.e., that abyssal habitats have sustained species radiations and are not merely sinks of non-reproducing individuals transported from ocean margins. In addition, there was significant evidence that the community structure of the foraminifera and polychaetes differs substantially over scales of 1,000 to 3,000 across the Clarion-Clipperton Zone.

11. The findings of the researchers suggested that protected areas should be established to safeguard biodiversity in the Clarion-Clipperton Zone in the face of anticipated nodule mining. They recommended that protected areas (referred to in the Authority's regulations as "preservation reference zones") should be set up as follows:

(a) Marine Protected Areas should be placed at multiple locations across the Clarion-Clipperton Zone, at the very least in the eastern, central and western portions of the region of mining claims;

(b) Because of the steep latitudinal gradients in productivity and community structure within the equatorial Pacific, the Marine Protected Areas should be designed to protect biodiversity across the entire width of the Clarion-Clipperton Zone, i.e., from latitude 7 degrees North to 17 degrees North;

(c) The Marine Protected Areas should be large enough to encompass major areas of the known benthic habitat types in the Clarion-Clipperton Zone, including abyssal hills with and without nodules, rocky ridges and multiple seamounts of various elevations above the seafloor;

(d) Each Marine Protected Area must be large enough for most of its area to be buffered from the direct and indirect impacts of nodule mining activities, including influences from sediment plumes in the water column and at the seafloor;

(e) Because benthic processes and community structure in the Clarion-Clipperton Zone are strongly influenced by processes in the water column above, it is highly desirable for management of the Marine Protected Areas to include control of substantial human activities (mining, energy exploitation, waste disposal and commercial fishing) from the abyssal seafloor to the ocean surface. This recommendation is consistent with the concept of ecosystem-based management.

12. It is important to recognize that the recommendations from the Kaplan project were based on a limited albeit rapidly growing database on biodiversity and species ranges in the Clarion-Clipperton Zone. Nevertheless, applying the precautionary approach, the results of the study suggest that where data are inadequate to exclude potential harm to the environment from a particular human activity (in this case nodule mining), the activity should be conservatively managed so as to ensure environmental protection.

IV. Future action

13. In October 2007, a group of scientists, including some of the principal researchers involved in the Kaplan project, met to develop a preliminary set of recommendations for criteria for determining the size and location of a network of representative preservation zones in the Clarion-Clipperton Zone. The draft recommendations will be presented to the Legal and Technical Commission and to the Council at the fourteenth session.

14. Based on the results of the Kaplan project, the Authority is in discussion with the Global Census of Marine Life on Seamounts with a view to conducting a similar study of the genetic make-up of plant and animal life found on seamounts.